Image $ AP 2862

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OIPE JC42 JAN 2 3 2004 PATENT & TRADEMARK OFFICE

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	10/056,747
Filing Date	January 24, 2002
First Named Inventor	Joakim O. Blanch
Art Unit	2862
Examiner Name	Toan M. Le
Total Number of Pages in This Submission: 28	Attorney Docket Number: 1391-26700

ENCLOSURES (check all that apply)

- ☒ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Response to Missing Parts/ Incomplete Application
  - ☐ Response to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s)
- ☐ After Allowance Communication to Group
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☒ Appeal Communication to Group *(Appeal Brief, in triplicate)*
- ☐ Proprietary Information
- ☐ Status Letter
- ☒ Other Enclosure(s) *(please identify below):* *Acknowledgement Post Card*

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Or Individual Name	Mark E. Scott, PTO Reg. No. 43,100 CONLEY ROSE, P.C.
Signature	Mark Scott
Date	January 20, 2004

CERTIFICATE OF TRANSMISSION/MAILING

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Typed or Printed Name	Ella R. Sisco		
Signature	Ella R. Sisco	Date	January 20, 2004

117935/1391-26700

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OIPE JAN 2 3 2004 JC42 PATENT & TRADEMARK OFFICE

FEE TRANSMITTAL For FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR §1.27

TOTAL AMOUNT OF PAYMENT $ 330.00

Complete if Known	
Application Number	10/056,747
Filing Date	January 24, 2002
First Named Inventor	Joakim O. Blanch
Examiner Name	Toan M. Le
Art Unit	2862
Attorney Docket No.	1391-26700

METHOD OF PAYMENT *(Check all that apply)*

☐ Check ☐ Credit Card ☐ Money Order ☐ Other ☐ None

☒ Deposit Account:
Deposit Account Number: 03-2769
Deposit Account Name: Conley Rose, P.C.

The Director is authorized to: (check all that apply)
☒ Charge fee(s) indicated below
☒ Charge any additional fee(s) during the pendency of this application
☐ Charge fee(s) indicated below, **except for the filing fee**
to the above-identified deposit account
☒ Credit any overpayments

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing Fee	$
1002	340	2002	170	Design filing fee	$
1003	530	2003	265	Plant filing fee	$
1004	770	2004	385	Reissue filing fee	$
1005	160	2005	80	Provisional filing fee	$

SUBTOTAL (1) $

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

		Extra Claims		Fee from below		Fee Paid
Total Claims	*	20** =	*	x 18.00	=	$
Independent Claims	*	3** =	*	x 86.00	=	$
Multiple Dependent				290.00	=	$ 00.00

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent Claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) $

*** or number previously paid, if greater; For Reissues, see above*

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	$
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	$
1053	130	1053	130	Non-English specification	$
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	$
18042	920*	1804	920*	Requesting publication of SIR prior to Examiner action	$
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	$
1251	110	2251	55	Extension for reply within first month	$
1252	420	2252	210	Extension for reply within second month	$
1253	950	2253	475	Extension for reply within third month	$
1254	1,480	2254	740	Extension for reply within fourth month	$
1255	2,010	2255	1,005	Extension for reply within fifth month	$
1401	330	2401	165	Notice of Appeal	$
1402	330	2402	165	Filing a Brief in support of an Appeal	$330.00
1403	280	2403	140	Request for oral hearing	$
1451	1,510	1452	1,510	Petition to institute a public use proceeding	$
1452	110	2452	55	Petition to revive - unavoidable	$
1453	1,330	2453	665	Petition to revive - unintentional	$
1501	1,330	2501	665	Utility issue fee (or reissue)	$
1502	480	2502	240	Design issue fee	$
1503	640	2503	320	Plant issue fee	$
1460	130	1460	130	Petitions to the Commissioner	$
1807	50	1806	50	Processing fee under 37 CFR 1.17(g)	$
123	50	123	50	Petitions related to provisional applications	$
1806	180	1806	180	Submission of Information Disclosure Stmt	$
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	$
1809	770	2809	385	Filing a submission after final rejection (37 CFR § 1.129(a))	$
1810	770	2810	385	For each additional invention to be examined (37 CFR § 1.129(b))	$
1801	770	2801	385	Request for Continued Examination (RCE)	$
1802	900	1802	900	Request for expedited examination of a design application	$

Other fee (specify) $

*Reduced by Basic Filing Fee Paid **SUBTOTAL (3) $330.00**

SUBMITTED BY				Complete *(if applicable)*	
Name *(Print/Type)*	Mark E. Scott	Registration No. *(Attorney/Agent)*	43,100	Telephone	(713) 238-8000
Signature	Mark Scott			Date	January 20, 2004

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117928/1391-26700

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s):	Joakim O. Blanch, et al.	§	
		§	
Serial No.:	10/056,747	§	
		§	Group Art Unit: 2862
Filed:	01/24/02	§	
		§	Examiner: Toan M. Le
For:	High Resolution Dispersion Estimation in Acoustic Well Logging	§ § §	

APPEAL BRIEF

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 4450
Alexandria, VA 22343-1450

Att'y. Docket No. 1391-26700
Client Ref. No. 2001-IP-004080
Date: January 20, 2004

Sir:

This paper is filed in response to the Office Action dated August 21, 2003 and the Notice of Appeal filed November 20, 2003.

I. REAL PARTY IN INTEREST

The real party in interest is the Assignee, Halliburton Energy Services, Inc.

II. RELATED APPEALS AND INTEFERENCES

None.

III. STATUS OF THE CLAIMS

Originally filed claims: 1-28.

Claims withdrawn in response to a restriction requirement: 12-20.

Claims reinstated after withdrawal of the restriction requirement: 12-20.

No new claims have been added.

Thus, claims 1-28 are pending, and all presently pending claims stand rejected.

IV. STATUS OF THE AMENDMENTS

There were no after-final amendments.

V. SUMMARY OF THE INVENTION

A. Brief Mathematical Background

Before discussing the specifics of the various embodiments of the invention, it may be helpful to discuss, in the abstract, the mathematical principles upon which application is based. The specifics of the various embodiments will be discussed in Section V(B).

Consider a vector $\vec{V}$ in three-dimensional Cartesian coordinate space, as shown in Figure 3A reproduced below.

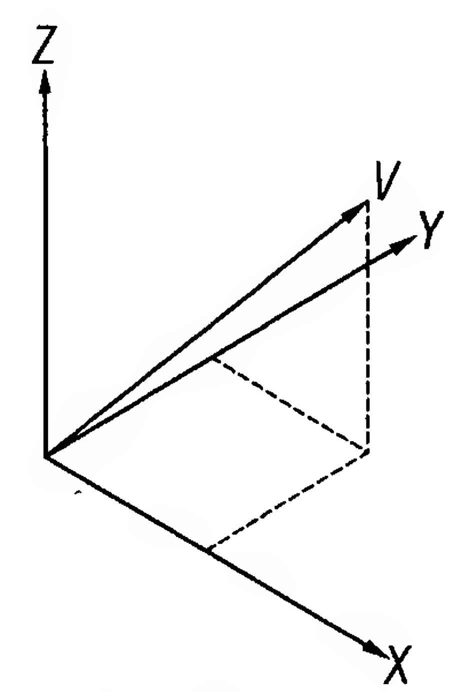

FIG. 3A

The vector $\vec{V}$ thus has components in each of the three directions X, Y and Z. Mathematically, the vector $\vec{V}$ may be represented as $\vec{V} = \lambda_x \vec{i} + \lambda_y \vec{j} + \lambda_z \vec{k}$, where $\vec{i}$, $\vec{j}$ and $\vec{k}$ are unit length vectors pointing in the *X, Y* and *Z* directions respectively, and where λ_x, λ_y and λ_z are values that indicate the contribution along the axis to the overall vector $\vec{V}$. *Specification* Paragraph [0028]. The unit length vectors $\vec{i}$, $\vec{j}$ and $\vec{k}$ may be referred to as eigenvectors, and the values λ_x, λ_y and λ_z may be referred to as eigenvalues. *Id.*

The coordinate system illustrated in Figure 3A may be used to fully describe any function, such as vector $\vec{V}$, because the eigenvectors define an orthogonal basis – hereinafter referred to as a "space." *Specification* Paragraph [0029]. If one of the eigenvectors is removed from consideration, then the remaining eigenvectors are said to define a "subspace" or "incomplete basis." *Id*; Claim 12. Using only a subspace it may be difficult to fully define or represent a function such as vector $\vec{V}$. *Specification* Paragraph [0030]. For example, using only a subspace comprising eigenvectors $\vec{i}$ and $\vec{j}$, the closest the subspace may come to representing vector $\vec{V}$ is $\bar{V} \cong \lambda_x \vec{i} + \lambda_y \vec{j}$. *Id.* Figure 3B, reproduced below, illustrates the situation of a subspace comprising only eigenvectors $\vec{i}$ and $\vec{j}$ attempting to represent the exemplary vector $\vec{V}$.

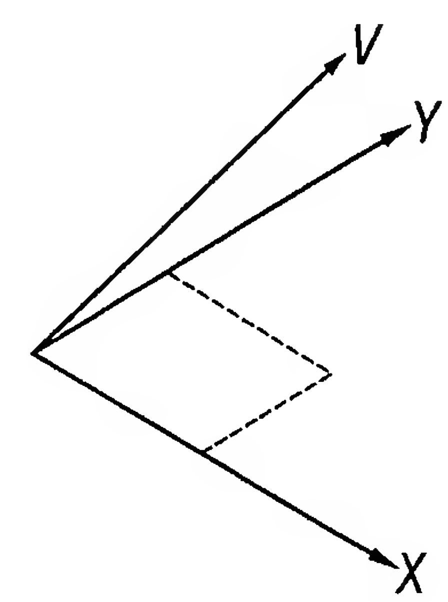

FIG. 3B

Thus, the exemplary vector $\vec{V}$ is not fully defined by the subspace as the vector has components in the Z direction that cannot be represented. *Id.* In this case, the vector $\vec{V}$ is said to map, at least partially, to the subspace.

In some cases, however, it may not be possible for the subspace to represent the function at all. Consider the situation of a different vector $\vec{V}$ comprised solely of Z axis components, as illustrated in Figure 3C below.

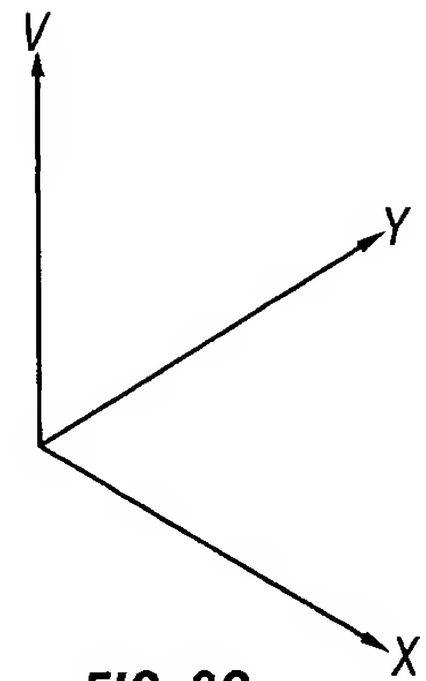

FIG. 3C

Regardless of the magnitude of the Z axis component, the exemplary subspace comprising only eigenvectors corresponding to the X and Y directions cannot represent the modified vector $\vec{V}$. *Specification* Paragraph [0030]. In this case, the vector $\vec{V}$ does not map to the subspace. *Id.*

Thus, if one is given a subspace and a test vector, by determining the extent to which the test vector maps to the subspace it is possible to determine whether the test vector more closely represents eigenvectors that make up the subspace, or eigenvectors that have been removed to create the subspace. *See Specification* Paragraph [0034].

B. Embodiments of the Invention

The various embodiments of the invention are directed to a downhole logging tool, for example a wireline acoustic logging tool. *Specification* Paragraphs [0021] – [0024]. As the tool is moved within a borehole, an acoustic transmitter periodically fires which induces acoustic waves in the formation. *Specification* Paragraph [0023]. As the acoustic waves propagate along the formation, receivers on the logging tool detect the energy of the acoustic waves and create time-series representations of the energy. *Id.* Figure 2A, reproduced below, shows an exemplary set of time-series received signals for a downhole tool having four receivers A, B, C and D spaced along the tool, with receiver A closest to the transmitter. Figure 2B is also reproduced.

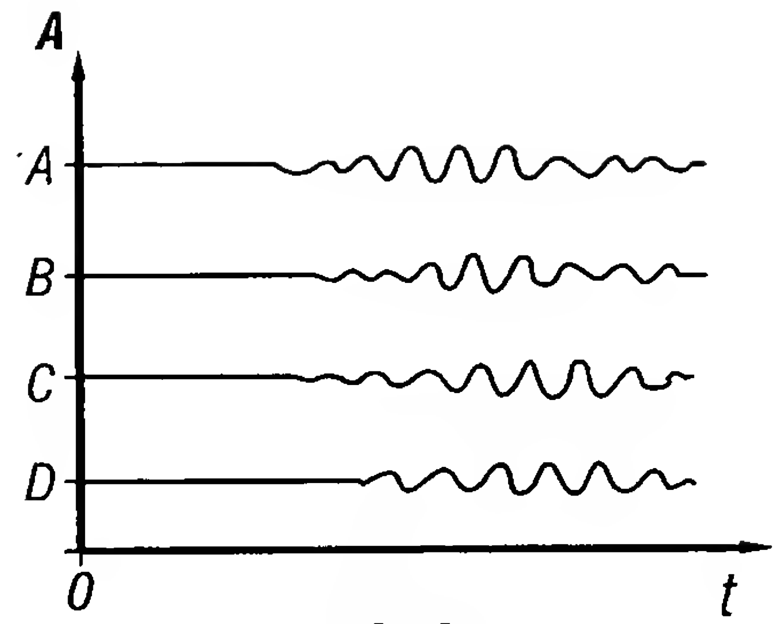

FIG. 2A

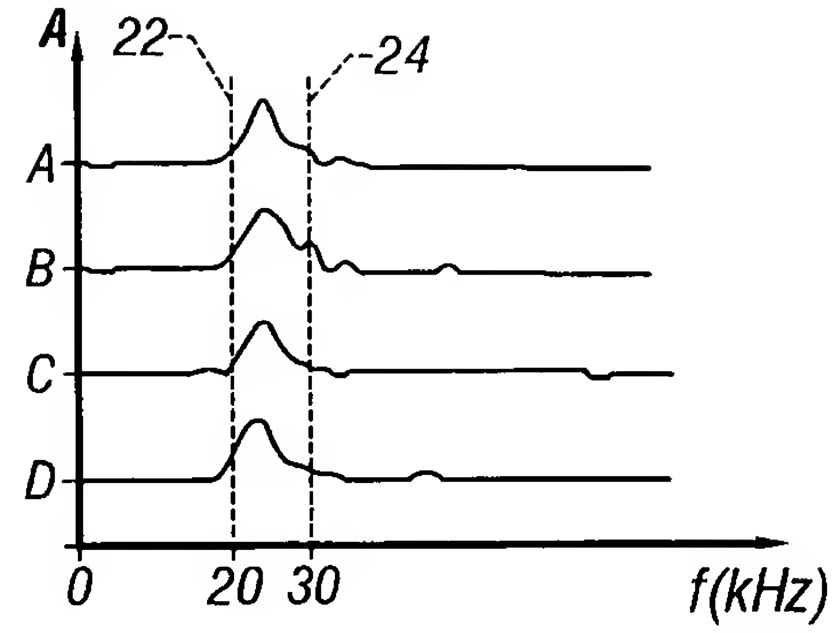

FIG. 2B

The time-series received signals are thereafter converted into their frequency domain counterparts by Fourier transform operations. *Specification* Paragraph [0008]. Figure 2B shows a corresponding set of frequency domain representations of the exemplary four received signals of Figure 2A. *Specification* Paragraph [0026].

The signal processing technique of the preferred embodiments comprises calculating a plurality of correlation matrices, each correlation matrix generated with data from each of the frequency domain representations of the received signals along a constant frequency. *Specification* Paragraph [0027]. For example, a correlation matrix is run for all the data points at 20 kilo-Hertz (*see* line 22 in Figure 2B above). *Specification* Paragraph [0031]. Likewise, a correlation matrix is run for all the data points at 30 kilo-Hertz (*see* line 24 in Figure 2B above), and the frequencies in-between. *Id.* Eigenvectors from each correlation matrix are determined, and all the eigenvectors together may be likened to the orthogonal basis or space from Section V(A) above. However, the eigenvectors of the various embodiments need not necessarily be straight lines as illustrated in Section V(A). *Specification* Paragraph [0029].

After determination of the eigenvectors, at least one of the higher order eigenvectors corresponding to a signal of interest is removed to create a subspace.[1] *Specification* Paragraphs [0032]-[0033]. The remaining eigenvectors may therefore correspond to noise in the received signals. *Id.* Before proceeding, it is noted that the eigenvectors removed, and thus the subspace created, are from actual data of received signals of the tool.

A series of test vectors is then applied to each subspace, each test vector based on a different assumed slowness (or inversely speed) of acoustic waves in the formation. *Specification* Paragraphs [0034] – [0037]. If a test vector maps or can be represented by the subspace, then the slowness embodied in the test vector corresponds to noise (because the eigenvectors corresponding to the signal of interest were removed to create the subspace). *Specification* Paragraph [0034]. Likewise, if the test vector does not map to, or cannot be represented by, the subspace, then the slowness embodied in the test vector corresponds to the actual signal of interest. In many cases, however, a test vector will partially map to the subspace, and the extent of the mapping is indicative whether the test vector correlates to signal or noise. *Id.* In order to quantify the extent of the mapping, the specification discloses an objective function of the form:

$$\frac{1}{\left|N_f W_f\right|^2}$$

[1] For purposes simplifying the discussion, only the case where higher order eigenvectors are removed is discussed. However, eigenvectors corresponding to signals of interest (*e.g.*, tool mode waves, casing mode waves, formation compression waves, formation shear waves) may be removed independent of whether they are the higher order eigenvectors. *Specification* Paragraph [0033]. Likewise, the situation may be reversed, and the lower order eigenvectors corresponding to noise may be removed, and thus the subspace may be based on signals of interest. *Id.*

where N_f is the test vector, and W_f is the subspace to which the test vector is applied. *Id.* When the test vector maps to the subspace, the value of the objective function is small. *Id.* When the test vector does not map to the subspace, the value of the objective function is large. *Id.*

Each calculated objective function may be plotted in a frequency versus slowness plot. Figure 5 is reproduced below as an example of a frequency versus slowness plot, with isometric lines showing areas where objective function values are substantially the same. *Specification* Paragraph [0035].

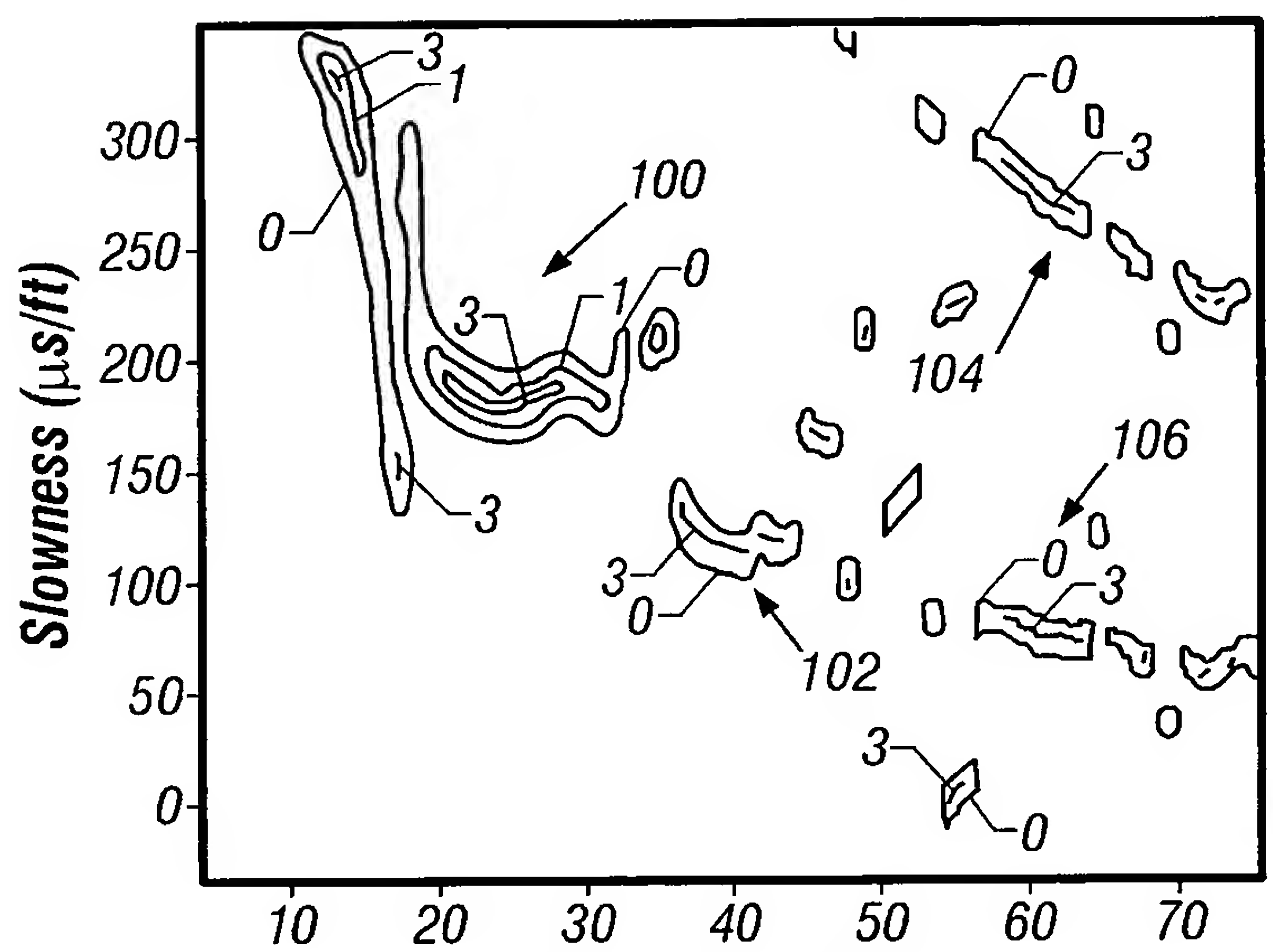

FIG. 5

In the frequency range spanning 20-30 kilohertz (which is the bulk of the frequency response indicated in the Frequency response graph of Figure 2B), the slowness is well defined and is approximately 175 μs/ft (region 100). *Id.* In the frequency range of approximately 35 to approximately 45 kHz, the slowness is approximately 125 μs/ft (region 102). *Id.* Finally, in the frequencies around 60 kHz, two slowness values are indicated (about 275 μs/ft for region 104 and about 75 μs/ft for region 106), exemplifying the response of an anisotropic formation. *Id.*

VI. ISSUES

Whether *Kimball* (U.S. Patent No. 6,449,560) anticipates claims 1-11.

Whether *Kimball* standing alone renders obvious claims 12-28.

VII. GROUPING OF THE CLAIMS

Claims 1-3, 5-12, 14-16, 18-24 and 26-28 stand together for purposes of this appeal.

Claims 4, 13, 17 and 25 stand together for purposes of this appeal.

The groupings above are for purposes of this appeal only. The groupings should not be construed to mean the patentability of any of the claims may be determined, in later actions before a court, based on the groupings. Rather, the presumption of 35 U.S.C. §282 shall apply to each claim individually.

VIII. ARGUMENT

The rejections formulated in the Office Action dated August 21, 2003 use a single reference, *Kimball*, as the basis for rejecting all the claims. Before discussing the particular shortcomings of the rejections, however, it is helpful to put into context the teachings of *Kimball*.

A. The *Kimball* Reference

Kimball is directed to signal processing for acoustic or sonic well logging where a reduced order propagator matrix is used. *Kimball* Title. *Kimball* discloses a wireline acoustic logging tool in which a plurality of receivers detect and create measurement data. *Kimball* Col. 5, line 11 – Col 6, line 40.

The mathematical basis for the signal processing method of *Kimball* is that receiver response can be simulated using a wave spectra for a particular wave type (*e.g.*, compressional, shear, Stoneley) and a model of formation response in the form of a propagator matrix. *Kimball* Col. 5, line 49-67. More particularly, *Kimball* discloses that model data x may be constructed as a

signal **s** combined with noise **n** (equation (2) below), where the signal **s** may be created using wave spectra of a particular wave type **a** and a propagator matrix $P(\Theta)$ (equation (1) below) where Θ are model parameters (*e.g.*, speed and attenuation). Thus, the mathematical relationships according to *Kimball* are defined as:

$$\underset{mnx1}{s} = \underset{mnxnq}{P(\Theta)} \; \underset{nqx1}{a} \tag{1}$$

$$\underset{mnx1}{x} = \underset{mnx1}{s} + \underset{mnx1}{n} \tag{2}$$

Kimball Col. 5, line 49-67. As an overview, *Kimball's* system involves generating a model propagator matrix $P(\Theta)$, and generating a "test statistic" indicative of the error between actual measurement data and the propagator matrix. "The maximized test statistic is indicative of a minimized error between data and [the] model." *Kimball* Col. 8, lines 65-68. In some cases, portions of the propagator matrix may be removed to create a reduced propagator matrix $P_e(\Theta)$, possibly to ease the computation burden on the system. *Kimball* Col. 6, lines 17-30: Col. 8, lines 41-49.

Turning now to the method embodied in *Kimball's* Figures 5A, 5B and 5C (reproduced in Appendix B beginning on page 24 of this paper). One of the initial steps in the *Kimball* processing may be deriving actual measuring data (block 702) and selecting model parameters (blocks 704, 707 and 710). *Kimball* Col. 9, line 64 – Col. 10, lines 21. Then a G^k matrix is calculated (block 715) for a particular wave type (*e.g.*, compressional, shear, Stoneley). *Kimball* Col. 10, lines 22-43. The G^k matrix[2] may comprise a filtering matrix $H^k(\Theta)$ and a windowing matrix $W^k(\Theta)$. *Kimball* Col. 7, lines 30-51; Equation 12; Figure 5A. Thus, each of $H^k(\Theta)$ and W^k (Θ) are a function of the model parameters. The G^k matrix is thereafter subjected to a singular value

[2] Referred to as the "intermediate matrix" in *Kimball's* claim 1.

decomposition to identify its eigenvectors[3] U^k (block 720). *Kimball* Col. 7, lines 52-59; Col. 10, lines 44-58.

After determining the matrix of eigenvectors, a portion of those eigenvectors are removed or truncated to create the reduced propagator $P_e(\Theta)$ (block 740). *Kimball* Col. 10, line 59 – Col. 11, line 6. *Kimball* discusses retaining only higher order components (eigenvectors with the largest magnitude eigenvalues) for the reduced propagator matrix. *Kimball* Col. 7, lines 52-60. Notice that the removal of eigenvectors is from the model propagator matrix.

Once the reduced propagator matrix $P_e(\Theta)$ is determined, the $P_e(\Theta)$ matrix is subjected to a singular value decomposition (block 740), and apparently only one of the components of the decomposition, $U_e(\Theta)$, is used in the calculation of the test statistic (block 765). *Kimball* Col. 11, lines 13-20. *Kimball* defines the test statistic to be $T(\Theta)=\left| U_e^T x \right|^2$. *Kimball* Col. 9, Equation 26; Col. 11, Equation 26. It is not until step 765, when the test statistic is calculated, that the actual measurement data $\boldsymbol{x}$ is used. At no time does *Kimball* discuss removing portions of the actual measurement data.

B. *Kimball* Does Not Teach or Render Obvious the Pending Claims.

1. Claims 1-3, 5-7, 9-12, 14, 15, 18-24, 26 and 28

Claim 12 is representative of the claims of the first grouping. Claim 12 is directed to a method of determining slowness (the inverse of acoustic velocity) of an earth formation. The method comprises, *inter alia*, calculating a correlation matrix from frequency domain representations of received acoustic signals at a particular frequency, determining eigenvectors and corresponding eigenvalues of the correlation matrix, removing at least one eigenvector to create incomplete basis, and calculating the value of an objective function. Claims 12-28 were rejected as

[3] The matrix of eigenvectors is referred to as a "basis matrix" in *Kimball's* claim 1.

allegedly obvious over *Kimball*. Claims 1-11 were rejected as alleged anticipated by *Kimball*; however, the distinction between the two rejections is that for claims 12-28 the Office Action dated August 21, 2003 admits *Kimball* does not teach plotting values. *See* Office Action dated August 21, 2003, Page 6, second full paragraph.

Applicants respectfully submit that *Kimball* does not teach or fairly suggest all the limitations of the claims of the grouping. In particular, *Kimball* does not teach or fairly suggest that a correlation matrix should be calculated from frequency-domain representations at a particular frequency. In rejecting these claims reliance is placed on *Kimball* Col. 14, lines 22-29 for an alleged teaching of calculating a correlation matrix. The citation is to claim elements (d), (e) and (f) of *Kimball's* claim 1. These claims elements, along with element (g), are reproduced below.

> (d) producing an intermediate matrix that is a function of a window matrix, said window matrix being a function of at least one of said model values;
> (e) performing a singular value decomposition on said intermediate matrix to obtain a basis matrix of eigenvectors;
> (f) deriving a propagator matrix as a function of said model values;
> (g) producing a reduced propagator matrix from said propagator matrix and said basis matrix.

Kimball Col. 14, lines 22-31. Noticeably absent from the citation, and from *Kimball* in general, is any mention of calculating a correlation matrix from components of each of the frequency domain representations at a particular frequency. The "intermediate matrix" of element (d) corresponds to the G^k matrix, which is neither a correlation matrix nor a matrix derived from actual measurement data. *Kimball* Col. 7, lines 30-48; Col. 10, lines 22-29. The "window matrix" of element (d) is a time-domain windowing matrix $W^k(\Theta)$, which is neither a correlation matrix nor a matrix derived from actual measurement data. *Kimball* Col. 7, lines 30-51; Equation 12; Figure 5A. The "basis matrix" of element (e) is the set of eigenvectors determined from the singular value decomposition

of the G^k matrix, which bias matrix is neither a correlation matrix nor a matrix derived from actual measurement data. *Kimball* Col. 7, lines 52-59; Col. 10, lines 44-58.

Based solely on the fact that the cited sections of *Kimball* fail to teach or fairly suggest the claimed calculating a correlation matrix from frequency domain representations of received acoustic signals, the rejection of the pending claims should be reversed and the claims allowed.

Notwithstanding the failure of *Kimball* with regard to correlation matrices, *Kimball* also fails to teach or farily suggest determining eigenvectors and corresponding eigenvalues of the received acoustic signals (in the form of the correlation matrices) or removing at least one of the eigenvectors. The correlation matrices of the Applicants' claims are based on the received data, and thus the determination of eigenvectors and eigenvalues is within respect to **actual data**. In rejecting these claims reliance is placed on *Kimball's* Col. 7, lines 53-57, and the portions of claim 1 reproduced above. However, the teaching of the cited locations is to determine eigenvectors of model parameters – **model space or model data**. *Kimball* does not teach, suggest or even imply eigenvectors and eigenvalues of measurement data should be determined, or further that at least one should be removed.

For this additional reason, all the rejections should be reversed and the claims allowed.

2. Claims 4, 13, 17 and 25

Claim 4 is representative of the claims of the grouping. Claim 4 is a method claim having all the limitations of claims 1 and 3, and further requiring that in creating of the subspace higher order eigenvectors are removed. Claim 4 was rejected as allegedly anticipated by *Kimball*. Claims 13, 17 and 25 were rejected as allegedly obvious over *Kimbal*.

Applicants respectfully submit that *Kimball* does not teach or render obvious all the limitations of claim 4. *Kimball* discusses determining eigenvectors and eigenvalues, but these

eigenvectors and eigenvalues are related to the propagator matrix -- **model space**. Claim 4, by contrast, specifically requires operations on eigenvectors related to received acoustic energy -- **data space**.

Moreover, *Kimball* teaches removing the **lower order eigenvectors and eigenvalues** by teaching that the approximation of a^k can be made using the first r_k eigenvectors of U^k. *Kimball* Col. 7, lines 59-62. Claim 4, by contrast, requires **removing higher order eigenvectors and eigenvalues**. Because *Kimball* operates in model space (as opposed to data space in Applicants' claim 4), and further *Kimball* teaches removal of lower order eigenvectors and eigenvalues (as opposed to removal of higher order eigenvectors and eigenvalues in Applicants' claim 4), *Kimball* does not teach, inherently contain, or fairly suggest the limitations of claim 4, and appears to be diametrically opposed to the limitations of claim 4.

With regard to those claims rejected as allegedly obvious over *Kimball*, "If the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims *prima facie* obvious." MPEP 2143.01; *In re Ratti*, 270 F.2d 810, 123 USPQ 349 (CCPA 1959). *Kimball* operates in the model space, and removes lower order eigenvectors and eigenvalues of the model. *Kimball* Col. 7, lines 52-60. To suggest that *Kimball* could be modified to operate in the data space, and to further suggest that *Kimball* could be modified to remove higher order eigenvectors and eigenvalues, changes the entire principle of operation of *Kimball*. Because the modifications suggested change the principle of operation, the obviousness rejections utilizing *Kimball* do not make a *prima facie* case.

Based on the forgoing, Applicants respectfully request that the rejections of this grouping of claims be reversed, and the claims allowed.

IX. CONCLUSION

Applicants respectfully request that the Examiner's rejections be reversed and the case set for issue.

In the course of the foregoing discussions, Applicants may have at times referred to claim limitations in shorthand fashion, or may have focused on a particular claim element. This discussion should not be interpreted to mean that the other limitations can be ignored or dismissed. The claims must be viewed as a whole, and each limitation of the claims must be considered when determining the patentability of the claims. Moreover, it should be understood that there may be other distinctions between the claims and the prior art which have yet to be raised, but which may be raised in the future.

If any fees are inadvertently omitted or if any additional fees are required or have been overpaid, please appropriately charge or credit those fees to Conley Rose, P.C. Deposit Account Number 03-2769/1391-26700.

Respectfully submitted,

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APPENDIX A
PENDING CLAIMS

1. (Previously Amended) In a system for acoustic logging of an earth formation comprising a transmitter creating acoustic energy and a plurality of receivers recording time domain representations of the acoustic energy as it traverses the earth formation, a method of signal processing to determine acoustic velocity as a function of frequency comprising:

converting the time domain representations of the acoustic energy into frequency domain representations;

creating a correlation matrix from amplitudes within the frequency domain representations at corresponding frequencies;

finding a plurality of component functions that define an orthogonal basis of the correlation matrix;

removing at least one component function to create a subspace; and

multiplying a test vector and the subspace, the test vector based on an estimated acoustic velocity of the earth formation, to determine whether the estimated acoustic velocity substantially matches the actual earth formation acoustic velocity.

2. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 wherein converting the time domain representations of the acoustic energy into frequency domain representations further comprises Fourier transforming each time domain representation to create each frequency domain representation.

3. (Previously Amended) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 wherein finding a plurality of component functions further comprises determining eigenvectors and eigenvalues of the correlation matrix.

4. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 3 wherein removing a component function to create a subspace further comprises removing a higher order eigenvector corresponding to received acoustic energy related to the acoustic energy created by the transmitter.

5. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 4 wherein removing a higher order eigenvector corresponding to received acoustic energy related to the acoustic energy created by the transmitter further comprises removing a plurality of higher order eigenvectors.

6. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 3 wherein removing at least one component function to create a subspace further comprises removing a lower order eigenvector corresponding to received noise.

7. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 6 wherein removing a lower order eigenvector corresponding to received noise further comprises removing a plurality of lower order eigenvectors.

8. (Previously Amended) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 wherein multiplying a test vector and the subspace to determine whether the estimated acoustic velocity substantially matches the actual earth formation acoustic velocity further comprises calculating an objective function using substantially the following equation:

$$\text{objective function} = \frac{1}{\left|N_f W_f\right|^2}$$

where N_f is the subspace and W_f is the test vector.

9. (Previously Amended) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 8 wherein the test vector takes substantially the form:

$$W_f = [1\ e^{-jds}\ e^{-j2ds}\ e^{-j3ds} \ldots\ e^{-j(n-x)ds}]$$

where d is the distance between the receivers, s is the estimated acoustic velocity, n is the total number of received signals and x is the number of removed eigenvectors.

10. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 further comprising repeating the multiplying step for a plurality of test vectors comprising a plurality of estimated acoustic velocities.

11. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 10 further comprising repeating the creating, finding, removing, multiplying steps for a plurality of corresponding frequencies.

12. (Original) In a system for acoustic logging of earth formations where a transmitter creates acoustic signals in the earth formation, a plurality of receivers detect the acoustic signals, and the acoustic signals are transformed into their frequency domain representations, a method of determining slowness of the earth formation as a function of frequency comprising:

calculating a correlation matrix from components of each of the frequency domain representations at a particular frequency;

determining eigenvectors and corresponding eigenvalues of the correlation matrix;

removing at least one eigenvector to create an incomplete basis;

calculating a value of an objective function indicative of the degree to which a test vector may be represented by the incomplete basis, the test vector based on an estimated slowness of the earth formation; and

plotting the value of the objective function as a function of the estimated slowness of the test vector and the particular frequency of the components of the frequency domain representations used to calculate the correlation matrix.

13. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 12 wherein removing at least one eigenvector to create an incomplete basis further comprises removing at least one higher order eigenvector, the removed at least one higher order eigenvector corresponding to acoustic signals, and the remaining eigenvectors corresponding to noise.

14. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 13 wherein calculating a value of an objective function indicative of

the degree to which a test vector may be represented by the incomplete basis further comprises calculating a value of an objective function indicative of the degree to which the test vector may be represented by the remaining eigenvectors corresponding to noise.

15. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 14 wherein calculating a value of an objective function indicative of the degree to which the test vector may be represented by the remaining eigenvectors corresponding to noise further comprises calculating a value of an objective function that approaches zero when the test vector may be substantially represented by the remaining eigenvectors.

16. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 15 calculating a value of an objective function that approaches zero when the test vector may be substantially represented by the remaining eigenvectors further comprises calculating the value of the objective function using substantially the following equation:

$$\frac{1}{\left|N_f W_f\right|^2}$$

where N_f is the incomplete basis and W_f is the test vector.

17. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 13 further comprising removing a plurality of higher order

eigenvectors, the removed higher order eigenvectors corresponding to acoustic signals, and the remaining eigenvectors corresponding to noise.

18. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 12 wherein removing at least one eigenvector to create an incomplete basis further comprises removing at least one lower order eigenvector, the removed at least one lower order eigenvector corresponding to noise, and the remaining eigenvectors corresponding to acoustic signals.

19. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 18 wherein calculating a value of an objective function indicative of the degree to which the test vector may be represented by the incomplete basis further comprises calculating a value of the objective function that approaches zero when the test vector may not be substantially represented by the remaining eigenvectors.

20. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 12 wherein the test vector takes substantially the form:

$$W_f = [1\ e^{-jds}\ e^{-j2ds}\ e^{-j3ds}\ \ldots\ e^{-j(n-r)ds}]$$

where d is the distance between the receivers, s is the estimated slowness, n is the total number of received signals and x is the number of removed eigenvectors.

21. (Original) A method of determining acoustic velocity and frequency dispersion of an earth formation using an acoustic tool, the method comprising:

a) sending acoustic energy into the earth formation from the acoustic tool;

b) detecting the acoustic energy in the earth formation at a plurality of receiver locations on the acoustic tool;

c) creating time series representations of the acoustic energy in the earth formation for each of the plurality of receiver locations;

d) Fourier transforming each of the time series representations to create a plurality of frequency domain representations;

e) creating a vector from values at a selected frequency in each of the plurality of frequency domain representations;

f) creating a correlation matrix from the vector;

g) determining the eigenvectors and eigenvalues of the correlation matrix;

h) removing at least one of the eigenvectors thereby creating a subspace;

i) determining a value that is indicative of the extent a test vector may be represented by the subspace, and wherein the test vector is based on an estimated acoustic velocity of the earth formation;

j) plotting the value as a function of the estimated acoustic velocity of the earth formation and the selected frequency;

k) repeating steps i) and j) for a plurality of estimated acoustic velocities; and

l) repeating steps e) through k) for a plurality of selected frequencies.

22. (Original) The method of determining acoustic velocity and frequency dispersion as defined in claim 21 further comprising:

wherein step a) further comprises sending acoustic energy into the earth formation at a depth level of interest; and

m) repeating steps a) through l) for a plurality of depth levels of interest.

23. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 21 wherein step a) further comprises sending acoustic energy into the earth formation using an acoustic transmitter.

24. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 21 wherein step b) further comprises detecting the acoustic energy in the earth formation with four acoustic receivers.

25. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 21 wherein step h) further comprises removing at least one higher order eigenvector, the removed at least one higher order eigenvector corresponding to desired acoustic signals, and the remaining eigenvectors corresponding to noise.

26. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 25 wherein step i) further comprises applying a test vector to the subspace with the result of the applying being the value indicative of the extent the test vector may be represented by the remaining eigenvectors corresponding to noise.

27. (Previously Amended) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 26 wherein applying a test vector to the subspace with the result of the applying being the value indicative of the extent the test vector may be represented by the remaining eigenvectors corresponding to noise further comprises applying substantially the following equation:

$$\text{result} = \frac{1}{\left|N_f W_f\right|^2}$$

where N_f is the subspace and W_f is the test vector.

28. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 27 wherein the test vector takes substantially the form:

$$W_f = [1\ e^{-jds}\ e^{-j2ds}\ e^{-j3ds} \ldots\ e^{-j(n-r)ds}]$$

where d is the distance between the receivers, s is the estimated acoustic velocity, n is the total number of received signals and r is the number of removed eigenvectors.

APPENDIX B
***KIMBALL'S* FIGURES 5A, 5B AND 5C**

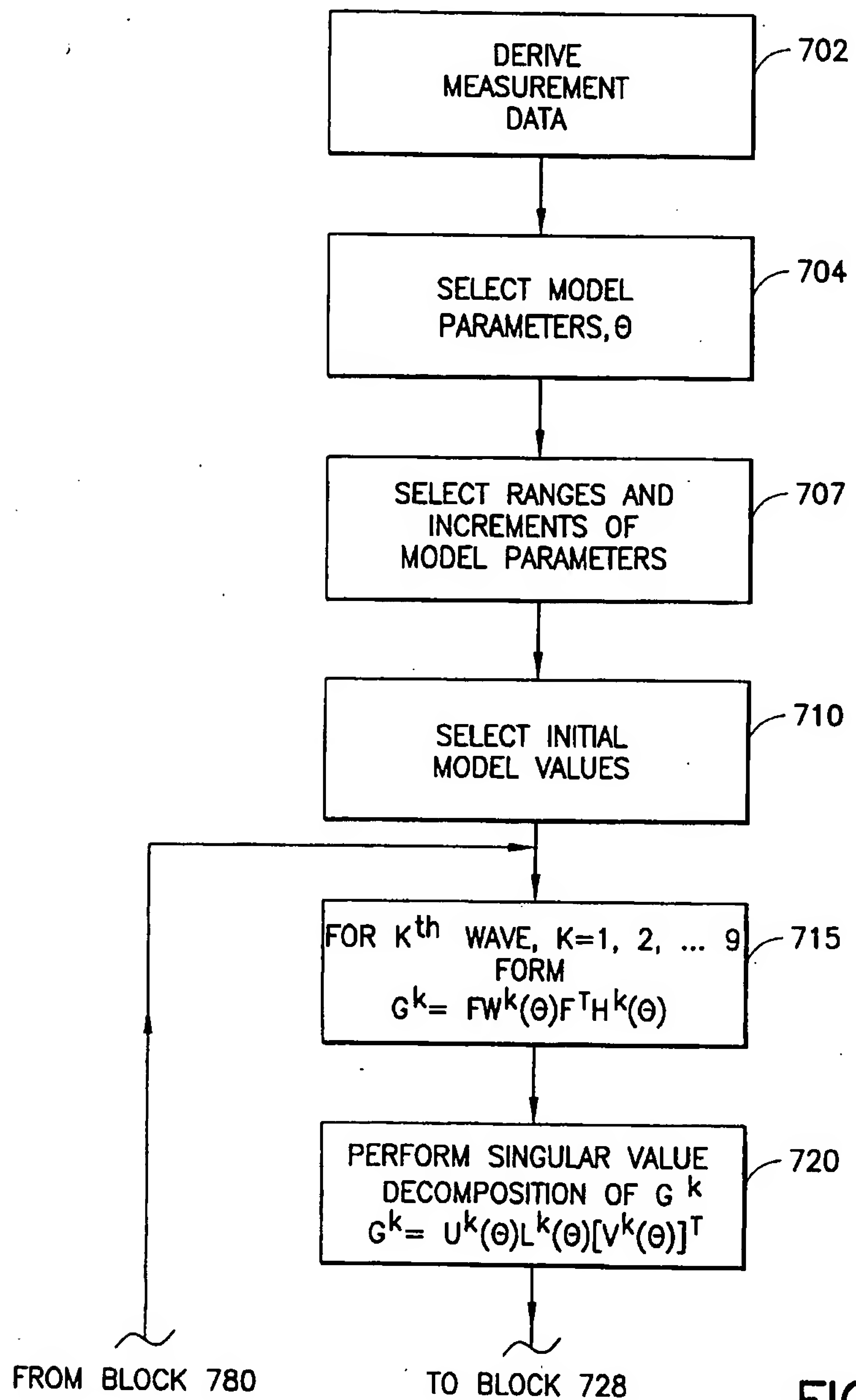

FIG.5A

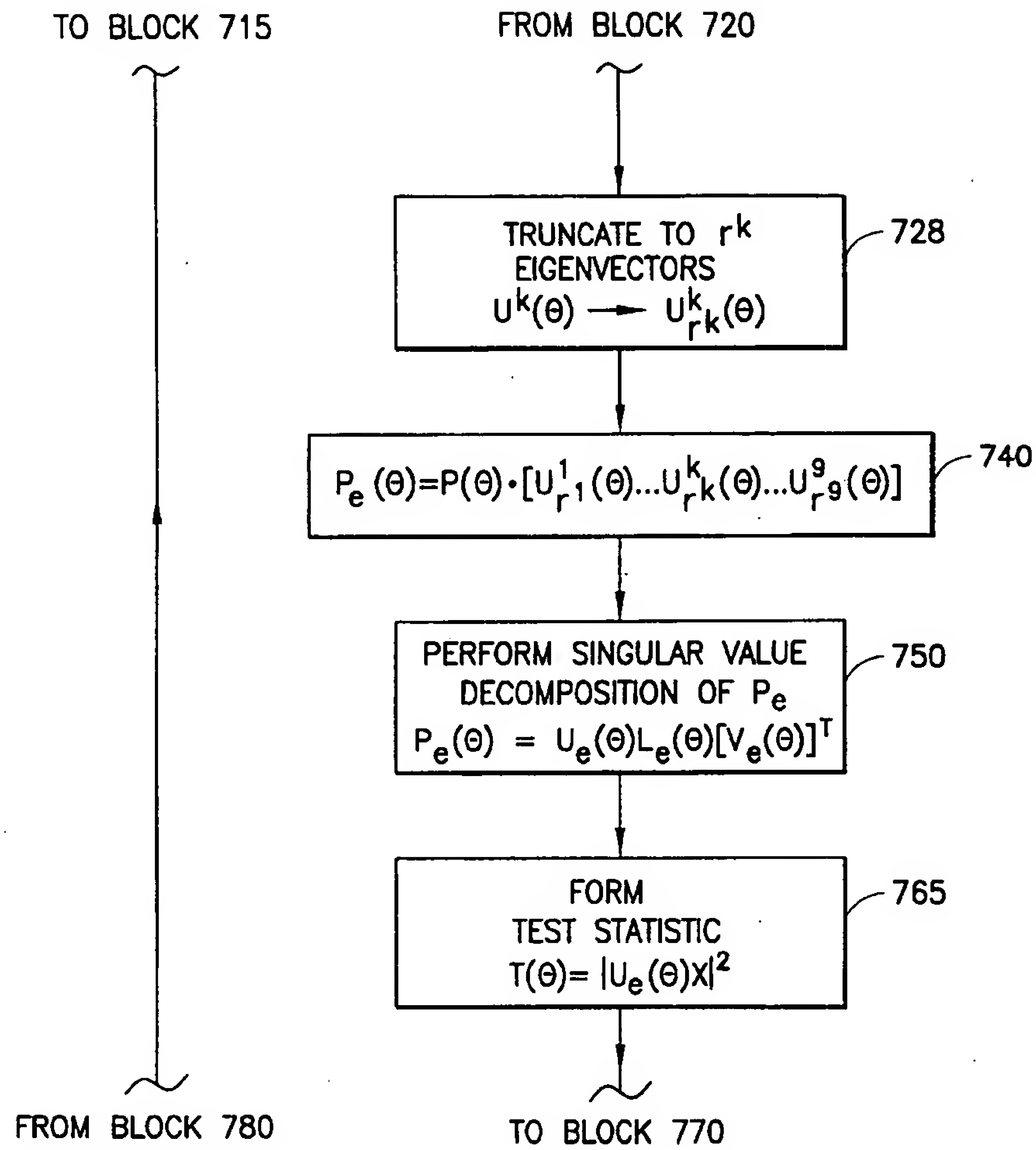
TO BLOCK 715
FROM BLOCK 720
TRUNCATE TO r^k EIGENVECTORS
$U^k(\Theta) \rightarrow U^k_{r^k}(\Theta)$
728
$P_e(\Theta)=P(\Theta)\cdot[U^1_{r^1}(\Theta)\ldots U^k_{r^k}(\Theta)\ldots U^9_{r^9}(\Theta)]$
740
PERFORM SINGULAR VALUE DECOMPOSITION OF P_e
$P_e(\Theta) = U_e(\Theta)L_e(\Theta)[V_e(\Theta)]^T$
750
FORM TEST STATISTIC
$T(\Theta)= |U_e(\Theta)X|^2$
765
FROM BLOCK 780
TO BLOCK 770

FIG.5B

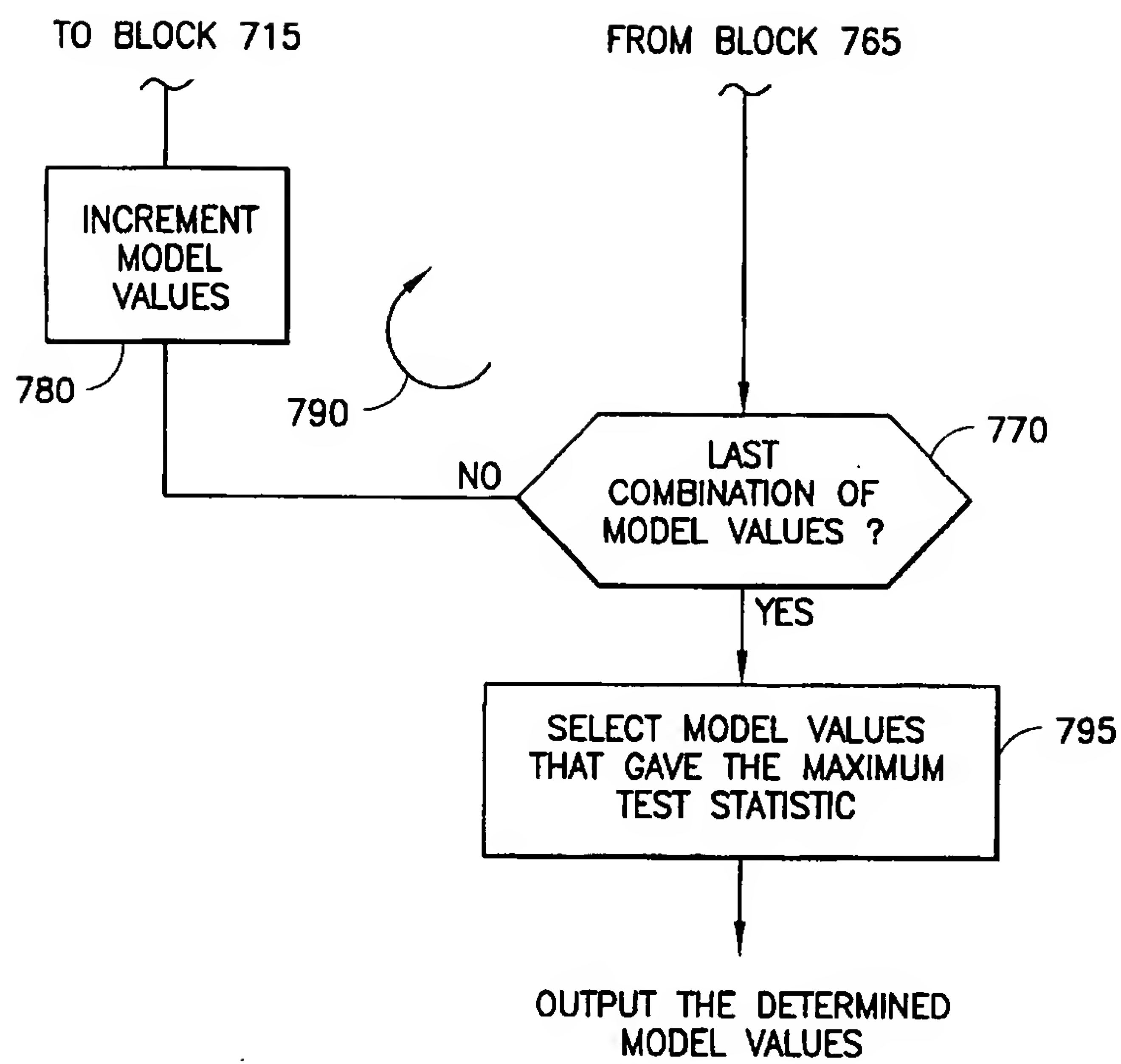
TO BLOCK 715
FROM BLOCK 765
INCREMENT MODEL VALUES
780
790
LAST COMBINATION OF MODEL VALUES ?
770
NO
YES
SELECT MODEL VALUES THAT GAVE THE MAXIMUM TEST STATISTIC
795
OUTPUT THE DETERMINED MODEL VALUES

FIG.5C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s):	Joakim O. Blanch, et al.	§	
		§	
Serial No.:	10/056,747	§	
		§	Group Art Unit: 2862
Filed:	01/24/02	§	
		§	Examiner: Toan M. Le
For:	High Resolution Dispersion Estimation in Acoustic Well Logging	§	
		§	
		§	

APPEAL BRIEF

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 4450
Alexandria, VA 22343-1450

Att'y. Docket No. 1391-26700
Client Ref. No. 2001-IP-004080
Date: January 20, 2004

Sir:

This paper is filed in response to the Office Action dated August 21, 2003 and the Notice of Appeal filed November 20, 2003.

I. REAL PARTY IN INTEREST

The real party in interest is the Assignee, Halliburton Energy Services, Inc.

II. RELATED APPEALS AND INTEFERENCES

None.

III. STATUS OF THE CLAIMS

Originally filed claims: 1-28.

Claims withdrawn in response to a restriction requirement: 12-20.

Claims reinstated after withdrawal of the restriction requirement: 12-20.

No new claims have been added.

Thus, claims 1-28 are pending, and all presently pending claims stand rejected.

IV. STATUS OF THE AMENDMENTS

There were no after-final amendments.

V. SUMMARY OF THE INVENTION

A. Brief Mathematical Background

Before discussing the specifics of the various embodiments of the invention, it may be helpful to discuss, in the abstract, the mathematical principles upon which application is based. The specifics of the various embodiments will be discussed in Section V(B).

Consider a vector $\vec{V}$ in three-dimensional Cartesian coordinate space, as shown in Figure 3A reproduced below.

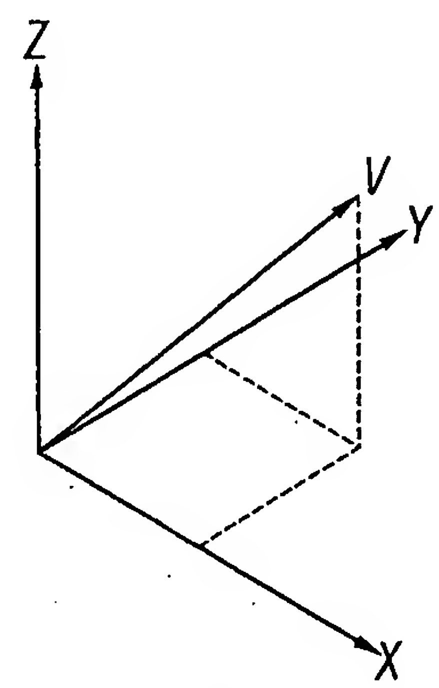

FIG. 3A

The vector $\vec{V}$ thus has components in each of the three directions X, Y and Z. Mathematically, the vector $\vec{V}$ may be represented as $\vec{V} = \lambda_x \vec{i} + \lambda_y \vec{j} + \lambda_z \vec{k}$, where $\vec{i}$, $\vec{j}$ and $\vec{k}$ are unit length vectors pointing in the *X*, *Y* and *Z* directions respectively, and where λ_x, λ_y and λ_z are values that indicate the contribution along the axis to the overall vector $\vec{V}$. *Specification* Paragraph [0028]. The unit length vectors $\vec{i}$, $\vec{j}$ and $\vec{k}$ may be referred to as eigenvectors, and the values λ_x, λ_y and λ_z may be referred to as eigenvalues. *Id.*

The coordinate system illustrated in Figure 3A may be used to fully describe any function, such as vector $\bar{V}$, because the eigenvectors define an orthogonal basis – hereinafter referred to as a "space." *Specification* Paragraph [0029]. If one of the eigenvectors is removed from consideration, then the remaining eigenvectors are said to define a "subspace" or "incomplete basis." *Id*; Claim 12. Using only a subspace it may be difficult to fully define or represent a function such as vector $\bar{V}$. *Specification* Paragraph [0030]. For example, using only a subspace comprising eigenvectors $\bar{i}$ and $\bar{j}$, the closest the subspace may come to representing vector $\bar{V}$ is $\bar{V} \cong \lambda_x \bar{i} + \lambda_y \bar{j}$. *Id.* Figure 3B, reproduced below, illustrates the situation of a subspace comprising only eigenvectors $\bar{i}$ and $\bar{j}$ attempting to represent the exemplary vector $\bar{V}$.

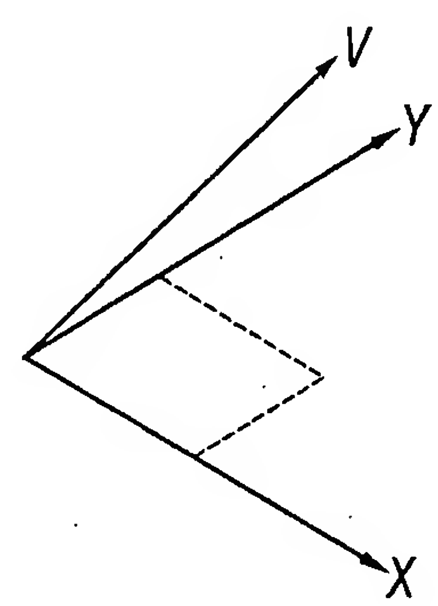

FIG. 3B

Thus, the exemplary vector $\bar{V}$ is not fully defined by the subspace as the vector has components in the Z direction that cannot be represented. *Id.* In this case, the vector $\bar{V}$ is said to map, at least partially, to the subspace.

In some cases, however, it may not be possible for the subspace to represent the function at all. Consider the situation of a different vector $\bar{V}$ comprised solely of Z axis components, as illustrated in Figure 3C below.

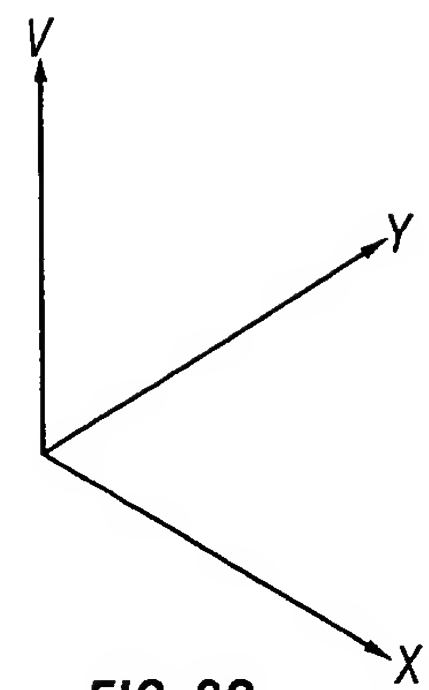

FIG. 3C

Regardless of the magnitude of the Z axis component, the exemplary subspace comprising only eigenvectors corresponding to the X and Y directions cannot represent the modified vector $\vec{V}$. *Specification* Paragraph [0030]. In this case, the vector $\vec{V}$ does not map to the subspace. *Id.*

Thus, if one is given a subspace and a test vector, by determining the extent to which the test vector maps to the subspace it is possible to determine whether the test vector more closely represents eigenvectors that make up the subspace, or eigenvectors that have been removed to create the subspace. *See Specification* Paragraph [0034].

B. Embodiments of the Invention

The various embodiments of the invention are directed to a downhole logging tool, for example a wireline acoustic logging tool. *Specification* Paragraphs [0021] – [0024]. As the tool is moved within a borehole, an acoustic transmitter periodically fires which induces acoustic waves in the formation. *Specification* Paragraph [0023]. As the acoustic waves propagate along the formation, receivers on the logging tool detect the energy of the acoustic waves and create time-series representations of the energy. *Id.* Figure 2A, reproduced below, shows an exemplary set of time-series received signals for a downhole tool having four receivers A, B, C and D spaced along the tool, with receiver A closest to the transmitter. Figure 2B is also reproduced.

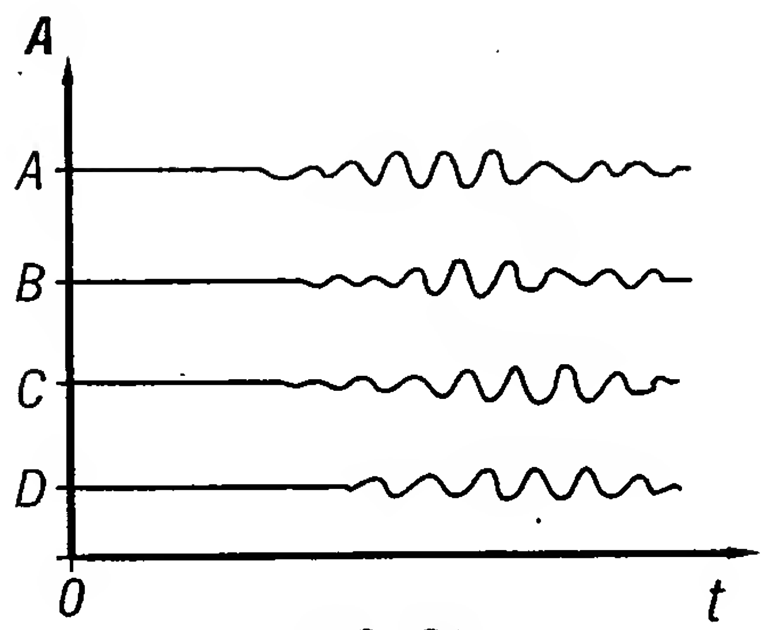

FIG. 2A

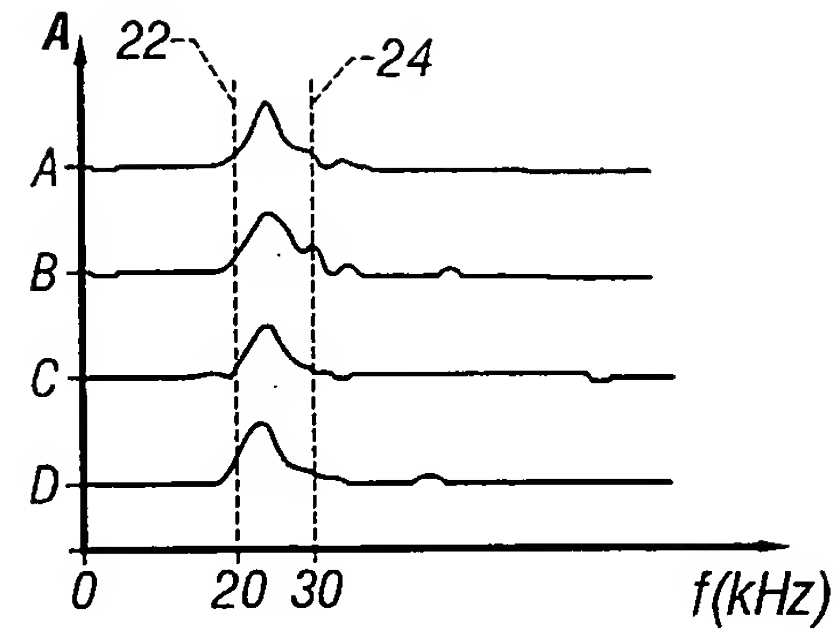

FIG. 2B

The time-series received signals are thereafter converted into their frequency domain counterparts by Fourier transform operations. *Specification* Paragraph [0008]. Figure 2B shows a corresponding set of frequency domain representations of the exemplary four received signals of Figure 2A. *Specification* Paragraph [0026].

The signal processing technique of the preferred embodiments comprises calculating a plurality of correlation matrices, each correlation matrix generated with data from each of the frequency domain representations of the received signals along a constant frequency. *Specification* Paragraph [0027]. For example, a correlation matrix is run for all the data points at 20 kilo-Hertz (*see* line 22 in Figure 2B above). *Specification* Paragraph [0031]. Likewise, a correlation matrix is run for all the data points at 30 kilo-Hertz (*see* line 24 in Figure 2B above), and the frequencies in-between. *Id.* Eigenvectors from each correlation matrix are determined, and all the eigenvectors together may be likened to the orthogonal basis or space from Section V(A) above. However, the eigenvectors of the various embodiments need not necessarily be straight lines as illustrated in Section V(A). *Specification* Paragraph [0029].

After determination of the eigenvectors, at least one of the higher order eigenvectors corresponding to a signal of interest is removed to create a subspace.[1] *Specification* Paragraphs [0032]-[0033]. The remaining eigenvectors may therefore correspond to noise in the received signals. *Id.* Before proceeding, it is noted that the eigenvectors removed, and thus the subspace created, are from actual data of received signals of the tool.

A series of test vectors is then applied to each subspace, each test vector based on a different assumed slowness (or inversely speed) of acoustic waves in the formation. *Specification* Paragraphs [0034] – [0037]. If a test vector maps or can be represented by the subspace, then the slowness embodied in the test vector corresponds to noise (because the eigenvectors corresponding to the signal of interest were removed to create the subspace). *Specification* Paragraph [0034]. Likewise, if the test vector does not map to, or cannot be represented by, the subspace, then the slowness embodied in the test vector corresponds to the actual signal of interest. In many cases, however, a test vector will partially map to the subspace, and the extent of the mapping is indicative whether the test vector correlates to signal or noise. *Id.* In order to quantify the extent of the mapping, the specification discloses an objective function of the form:

$$\frac{1}{\left|N_f W_f\right|^2}$$

[1] For purposes simplifying the discussion, only the case where higher order eigenvectors are removed is discussed. However, eigenvectors corresponding to signals of interest (*e.g.*, tool mode waves, casing mode waves, formation compression waves, formation shear waves) may be removed independent of whether they are the higher order eigenvectors. *Specification* Paragraph [0033]. Likewise, the situation may be reversed, and the lower order eigenvectors corresponding to noise may be removed, and thus the subspace may be based on signals of interest. *Id.*

where N_f is the test vector, and W_f is the subspace to which the test vector is applied. *Id.* When the test vector maps to the subspace, the value of the objective function is small. *Id.* When the test vector does not map to the subspace, the value of the objective function is large. *Id.*

Each calculated objective function may be plotted in a frequency versus slowness plot. Figure 5 is reproduced below as an example of a frequency versus slowness plot, with isometric lines showing areas where objective function values are substantially the same. *Specification* Paragraph [0035].

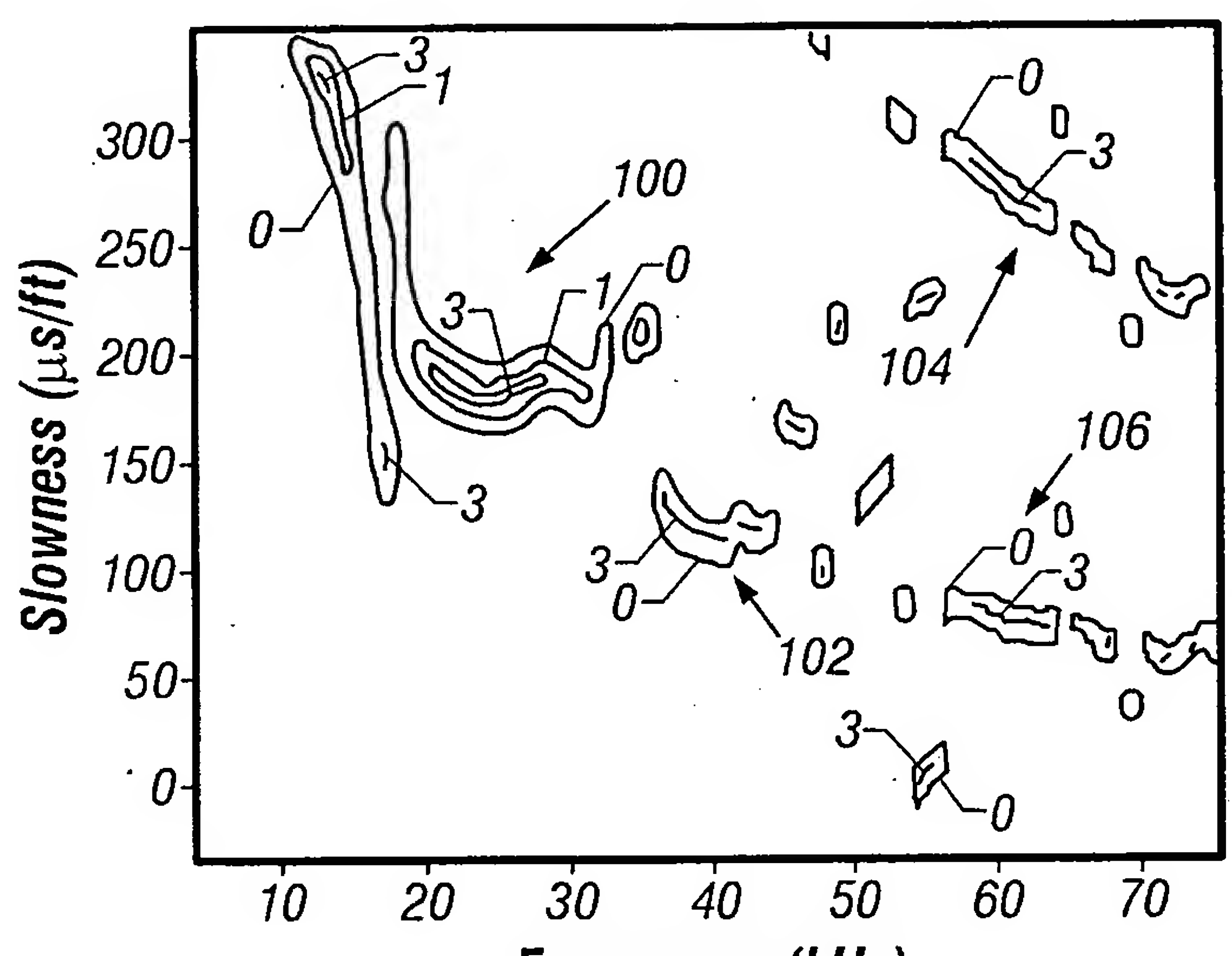

FIG. 5

In the frequency range spanning 20-30 kilohertz (which is the bulk of the frequency response indicated in the Frequency response graph of Figure 2B), the slowness is well defined and is approximately 175 μs/ft (region 100). *Id.* In the frequency range of approximately 35 to approximately 45 kHz, the slowness is approximately 125 μs/ft (region 102). *Id.* Finally, in the frequencies around 60 kHz, two slowness values are indicated (about 275 μs/ft for region 104 and about 75 μs/ft for region 106), exemplifying the response of an anisotropic formation. *Id.*

VI. ISSUES

Whether *Kimball* (U.S. Patent No. 6,449,560) anticipates claims 1-11.

Whether *Kimball* standing alone renders obvious claims 12-28.

VII. GROUPING OF THE CLAIMS

Claims 1-3, 5-12, 14-16, 18-24 and 26-28 stand together for purposes of this appeal.

Claims 4, 13, 17 and 25 stand together for purposes of this appeal.

The groupings above are for purposes of this appeal only. The groupings should not be construed to mean the patentability of any of the claims may be determined, in later actions before a court, based on the groupings. Rather, the presumption of 35 U.S.C. §282 shall apply to each claim individually.

VIII. ARGUMENT

The rejections formulated in the Office Action dated August 21, 2003 use a single reference, *Kimball*, as the basis for rejecting all the claims. Before discussing the particular shortcomings of the rejections, however, it is helpful to put into context the teachings of *Kimball*.

A. The *Kimball* Reference

Kimball is directed to signal processing for acoustic or sonic well logging where a reduced order propagator matrix is used. *Kimball* Title. *Kimball* discloses a wireline acoustic logging tool in which a plurality of receivers detect and create measurement data. *Kimball* Col. 5, line 11 – Col 6, line 40.

The mathematical basis for the signal processing method of *Kimball* is that receiver response can be simulated using a wave spectra for a particular wave type (*e.g.*, compressional, shear, Stoneley) and a model of formation response in the form of a propagator matrix. *Kimball* Col. 5, line 49-67. More particularly, *Kimball* discloses that model data x may be constructed as a

signal $\boldsymbol{s}$ combined with noise $\boldsymbol{n}$ (equation (2) below), where the signal $\boldsymbol{s}$ may be created using wave spectra of a particular wave type $\boldsymbol{a}$ and a propagator matrix $P(\Theta)$ (equation (1) below) where Θ are model parameters (*e.g.*, speed and attenuation). Thus, the mathematical relationships according to *Kimball* are defined as:

$$\underset{mnx1}{s} = \underset{mnxnq}{P(\Theta)} \; \underset{nqx1}{a} \tag{1}$$

$$\underset{mnx1}{x} = \underset{mnx1}{s} + \underset{mnx1}{n} \tag{2}$$

Kimball Col. 5, line 49-67. As an overview, *Kimball's* system involves generating a model propagator matrix $P(\Theta)$, and generating a "test statistic" indicative of the error between actual measurement data and the propagator matrix. "The maximized test statistic is indicative of a minimized error between data and [the] model." *Kimball* Col. 8, lines 65-68. In some cases, portions of the propagator matrix may be removed to create a reduced propagator matrix $P_e(\Theta)$, possibly to ease the computation burden on the system. *Kimball* Col. 6, lines 17-30: Col. 8, lines 41-49.

Turning now to the method embodied in *Kimball's* Figures 5A, 5B and 5C (reproduced in Appendix B beginning on page 24 of this paper). One of the initial steps in the *Kimball* processing may be deriving actual measuring data (block 702) and selecting model parameters (blocks 704, 707 and 710). *Kimball* Col. 9, line 64 – Col. 10, lines 21. Then a G^k matrix is calculated (block 715) for a particular wave type (*e.g.*, compressional, shear, Stoneley). *Kimball* Col. 10, lines 22-43. The G^k matrix[2] may comprise a filtering matrix $H^k(\Theta)$ and a windowing matrix $W^k(\Theta)$. *Kimball* Col. 7, lines 30-51; Equation 12; Figure 5A. Thus, each of $H^k(\Theta)$ and W^k (Θ) are a function of the model parameters. The G^k matrix is thereafter subjected to a singular value

[2] Referred to as the "intermediate matrix" in *Kimball's* claim 1.

decomposition to identify its eigenvectors[3] U^k (block 720). *Kimball* Col. 7, lines 52-59; Col. 10, lines 44-58.

After determining the matrix of eigenvectors, a portion of those eigenvectors are removed or truncated to create the reduced propagator $P_e(\Theta)$ (block 740). *Kimball* Col. 10, line 59 – Col. 11, line 6. *Kimball* discusses retaining only higher order components (eigenvectors with the largest magnitude eigenvalues) for the reduced propagator matrix. *Kimball* Col. 7, lines 52-60. Notice that the removal of eigenvectors is from the model propagator matrix.

Once the reduced propagator matrix $P_e(\Theta)$ is determined, the $P_e(\Theta)$ matrix is subjected to a singular value decomposition (block 740), and apparently only one of the components of the decomposition, $U_e(\Theta)$, is used in the calculation of the test statistic (block 765). *Kimball* Col. 11, lines 13-20. *Kimball* defines the test statistic to be $T(\Theta)=\left| U_e^T x \right|^2$. *Kimball* Col. 9, Equation 26; Col. 11, Equation 26. It is not until step 765, when the test statistic is calculated, that the actual measurement data x is used. At no time does *Kimball* discuss removing portions of the actual measurement data.

B. *Kimball* Does Not Teach or Render Obvious the Pending Claims.

1. Claims 1-3, 5-7, 9-12, 14, 15, 18-24, 26 and 28

Claim 12 is representative of the claims of the first grouping. Claim 12 is directed to a method of determining slowness (the inverse of acoustic velocity) of an earth formation. The method comprises, *inter alia*, calculating a correlation matrix from frequency domain representations of received acoustic signals at a particular frequency, determining eigenvectors and corresponding eigenvalues of the correlation matrix, removing at least one eigenvector to create incomplete basis, and calculating the value of an objective function. Claims 12-28 were rejected as

[3] The matrix of eigenvectors is referred to as a "basis matrix" in *Kimball's* claim 1.

allegedly obvious over *Kimball*. Claims 1-11 were rejected as alleged anticipated by *Kimball*; however, the distinction between the two rejections is that for claims 12-28 the Office Action dated August 21, 2003 admits *Kimball* does not teach plotting values. *See* Office Action dated August 21, 2003, Page 6, second full paragraph.

Applicants respectfully submit that *Kimball* does not teach or fairly suggest all the limitations of the claims of the grouping. In particular, *Kimball* does not teach or fairly suggest that a correlation matrix should be calculated from frequency-domain representations at a particular frequency. In rejecting these claims reliance is placed on *Kimball* Col. 14, lines 22-29 for an alleged teaching of calculating a correlation matrix. The citation is to claim elements (d), (e) and (f) of *Kimball's* claim 1. These claims elements, along with element (g), are reproduced below.

> (d) producing an intermediate matrix that is a function of a window matrix, said window matrix being a function of at least one of said model values;
> (e) performing a singular value decomposition on said intermediate matrix to obtain a basis matrix of eigenvectors;
> (f) deriving a propagator matrix as a function of said model values;
> (g) producing a reduced propagator matrix from said propagator matrix and said basis matrix.

Kimball Col. 14, lines 22-31. Noticeably absent from the citation, and from *Kimball* in general, is any mention of calculating a correlation matrix from components of each of the frequency domain representations at a particular frequency. The "intermediate matrix" of element (d) corresponds to the G^k matrix, which is neither a correlation matrix nor a matrix derived from actual measurement data. *Kimball* Col. 7, lines 30-48; Col. 10, lines 22-29. The "window matrix" of element (d) is a time-domain windowing matrix $W^k(\Theta)$, which is neither a correlation matrix nor a matrix derived from actual measurement data. *Kimball* Col. 7, lines 30-51; Equation 12; Figure 5A. The "basis matrix" of element (e) is the set of eigenvectors determined from the singular value decomposition

of the G^k matrix, which bias matrix is neither a correlation matrix nor a matrix derived from actual measurement data. *Kimball* Col. 7, lines 52-59; Col. 10, lines 44-58.

Based solely on the fact that the cited sections of *Kimball* fail to teach or fairly suggest the claimed calculating a correlation matrix from frequency domain representations of received acoustic signals, the rejection of the pending claims should be reversed and the claims allowed.

Notwithstanding the failure of *Kimball* with regard to correlation matrices, *Kimball* also fails to teach or farily suggest determining eigenvectors and corresponding eigenvalues of the received acoustic signals (in the form of the correlation matrices) or removing at least one of the eigenvectors. The correlation matrices of the Applicants' claims are based on the received data, and thus the determination of eigenvectors and eigenvalues is within respect to **actual data**. In rejecting these claims reliance is placed on *Kimball's* Col. 7, lines 53-57, and the portions of claim 1 reproduced above. However, the teaching of the cited locations is to determine eigenvectors of model parameters – **model space or model data**. *Kimball* does not teach, suggest or even imply eigenvectors and eigenvalues of measurement data should be determined, or further that at least one should be removed.

For this additional reason, all the rejections should be reversed and the claims allowed.

2. Claims 4, 13, 17 and 25

Claim 4 is representative of the claims of the grouping. Claim 4 is a method claim having all the limitations of claims 1 and 3, and further requiring that in creating of the subspace higher order eigenvectors are removed. Claim 4 was rejected as allegedly anticipated by *Kimball*. Claims 13, 17 and 25 were rejected as allegedly obvious over *Kimbal.*

Applicants respectfully submit that *Kimball* does not teach or render obvious all the limitations of claim 4. *Kimball* discusses determining eigenvectors and eigenvalues, but these

eigenvectors and eigenvalues are related to the propagator matrix -- **model space**. Claim 4, by contrast, specifically requires operations on eigenvectors related to received acoustic energy -- **data space**.

Moreover, *Kimball* teaches removing the **lower order eigenvectors and eigenvalues** by teaching that the approximation of a^k can be made using the first r_k eigenvectors of U^k. *Kimball* Col. 7, lines 59-62. Claim 4, by contrast, requires **removing higher order eigenvectors and eigenvalues**. Because *Kimball* operates in model space (as opposed to data space in Applicants' claim 4), and further *Kimball* teaches removal of lower order eigenvectors and eigenvalues (as opposed to removal of higher order eigenvectors and eigenvalues in Applicants' claim 4), *Kimball* does not teach, inherently contain, or fairly suggest the limitations of claim 4, and appears to be diametrically opposed to the limitations of claim 4.

With regard to those claims rejected as allegedly obvious over *Kimball*, "If the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the claims *prima facie* obvious." MPEP 2143.01; *In re Ratti*, 270 F.2d 810, 123 USPQ 349 (CCPA 1959). *Kimball* operates in the model space, and removes lower order eigenvectors and eigenvalues of the model. *Kimball* Col. 7, lines 52-60. To suggest that *Kimball* could be modified to operate in the data space, and to further suggest that *Kimball* could be modified to remove higher order eigenvectors and eigenvalues, changes the entire principle of operation of *Kimball*. Because the modifications suggested change the principle of operation, the obviousness rejections utilizing *Kimball* do not make a *prima facie* case.

Based on the forgoing, Applicants respectfully request that the rejections of this grouping of claims be reversed, and the claims allowed.

IX. CONCLUSION

Applicants respectfully request that the Examiner's rejections be reversed and the case set for issue.

In the course of the foregoing discussions, Applicants may have at times referred to claim limitations in shorthand fashion, or may have focused on a particular claim element. This discussion should not be interpreted to mean that the other limitations can be ignored or dismissed. The claims must be viewed as a whole, and each limitation of the claims must be considered when determining the patentability of the claims. Moreover, it should be understood that there may be other distinctions between the claims and the prior art which have yet to be raised, but which may be raised in the future.

If any fees are inadvertently omitted or if any additional fees are required or have been overpaid, please appropriately charge or credit those fees to Conley Rose, P.C. Deposit Account Number 03-2769/1391-26700.

Respectfully submitted,

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APPENDIX A
PENDING CLAIMS

1. (Previously Amended) In a system for acoustic logging of an earth formation comprising a transmitter creating acoustic energy and a plurality of receivers recording time domain representations of the acoustic energy as it traverses the earth formation, a method of signal processing to determine acoustic velocity as a function of frequency comprising:

converting the time domain representations of the acoustic energy into frequency domain representations;

creating a correlation matrix from amplitudes within the frequency domain representations at corresponding frequencies;

finding a plurality of component functions that define an orthogonal basis of the correlation matrix;

removing at least one component function to create a subspace; and

multiplying a test vector and the subspace, the test vector based on an estimated acoustic velocity of the earth formation, to determine whether the estimated acoustic velocity substantially matches the actual earth formation acoustic velocity.

2. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 wherein converting the time domain representations of the acoustic energy into frequency domain representations further comprises Fourier transforming each time domain representation to create each frequency domain representation.

3. (Previously Amended) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 wherein finding a plurality of component functions further comprises determining eigenvectors and eigenvalues of the correlation matrix.

4. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 3 wherein removing a component function to create a subspace further comprises removing a higher order eigenvector corresponding to received acoustic energy related to the acoustic energy created by the transmitter.

5. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 4 wherein removing a higher order eigenvector corresponding to received acoustic energy related to the acoustic energy created by the transmitter further comprises removing a plurality of higher order eigenvectors.

6. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 3 wherein removing at least one component function to create a subspace further comprises removing a lower order eigenvector corresponding to received noise.

7. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 6 wherein removing a lower order eigenvector corresponding to received noise further comprises removing a plurality of lower order eigenvectors.

8. (Previously Amended) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 wherein multiplying a test vector and the subspace to determine whether the estimated acoustic velocity substantially matches the actual earth formation acoustic velocity further comprises calculating an objective function using substantially the following equation:

$$\text{objective function} = \frac{1}{\left|N_f W_f\right|^2}$$

where N_f is the subspace and W_f is the test vector.

9. (Previously Amended) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 8 wherein the test vector takes substantially the form:

$$W_f = [1\ e^{-jds}\ e^{-j2ds}\ e^{-j3ds}\ \ldots\ e^{-j(n-x)ds}]$$

where d is the distance between the receivers, s is the estimated acoustic velocity, n is the total number of received signals and x is the number of removed eigenvectors.

10. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 1 further comprising repeating the multiplying step for a plurality of test vectors comprising a plurality of estimated acoustic velocities.

11. (Original) The method of signal processing to determine acoustic velocity as a function of frequency as defined in claim 10 further comprising repeating the creating, finding, removing, multiplying steps for a plurality of corresponding frequencies.

12. (Original) In a system for acoustic logging of earth formations where a transmitter creates acoustic signals in the earth formation, a plurality of receivers detect the acoustic signals, and the acoustic signals are transformed into their frequency domain representations, a method of determining slowness of the earth formation as a function of frequency comprising:

calculating a correlation matrix from components of each of the frequency domain representations at a particular frequency;

determining eigenvectors and corresponding eigenvalues of the correlation matrix;

removing at least one eigenvector to create an incomplete basis;

calculating a value of an objective function indicative of the degree to which a test vector may be represented by the incomplete basis, the test vector based on an estimated slowness of the earth formation; and

plotting the value of the objective function as a function of the estimated slowness of the test vector and the particular frequency of the components of the frequency domain representations used to calculate the correlation matrix.

13. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 12 wherein removing at least one eigenvector to create an incomplete basis further comprises removing at least one higher order eigenvector, the removed at least one higher order eigenvector corresponding to acoustic signals, and the remaining eigenvectors corresponding to noise.

14. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 13 wherein calculating a value of an objective function indicative of

the degree to which a test vector may be represented by the incomplete basis further comprises calculating a value of an objective function indicative of the degree to which the test vector may be represented by the remaining eigenvectors corresponding to noise.

15. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 14 wherein calculating a value of an objective function indicative of the degree to which the test vector may be represented by the remaining eigenvectors corresponding to noise further comprises calculating a value of an objective function that approaches zero when the test vector may be substantially represented by the remaining eigenvectors.

16. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 15 calculating a value of an objective function that approaches zero when the test vector may be substantially represented by the remaining eigenvectors further comprises calculating the value of the objective function using substantially the following equation:

$$\frac{1}{|N_f W_f|^2}$$

where N_f is the incomplete basis and W_f is the test vector.

17. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 13 further comprising removing a plurality of higher order

eigenvectors, the removed higher order eigenvectors corresponding to acoustic signals, and the remaining eigenvectors corresponding to noise.

18. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 12 wherein removing at least one eigenvector to create an incomplete basis further comprises removing at least one lower order eigenvector, the removed at least one lower order eigenvector corresponding to noise, and the remaining eigenvectors corresponding to acoustic signals.

19. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 18 wherein calculating a value of an objective function indicative of the degree to which the test vector may be represented by the incomplete basis further comprises calculating a value of the objective function that approaches zero when the test vector may not be substantially represented by the remaining eigenvectors.

20. (Original) The method of determining slowness of the earth formation as a function of frequency as defined in claim 12 wherein the test vector takes substantially the form:

$$W_f = [1\ e^{-jds}\ e^{-j2ds}\ e^{-j3ds} \ldots\ e^{-j(n-r)ds}]$$

where d is the distance between the receivers, s is the estimated slowness, n is the total number of received signals and x is the number of removed eigenvectors.

21. (Original) A method of determining acoustic velocity and frequency dispersion of an earth formation using an acoustic tool, the method comprising:

a) sending acoustic energy into the earth formation from the acoustic tool;

b) detecting the acoustic energy in the earth formation at a plurality of receiver locations on the acoustic tool;

c) creating time series representations of the acoustic energy in the earth formation for each of the plurality of receiver locations;

d) Fourier transforming each of the time series representations to create a plurality of frequency domain representations;

e) creating a vector from values at a selected frequency in each of the plurality of frequency domain representations;

f) creating a correlation matrix from the vector;

g) determining the eigenvectors and eigenvalues of the correlation matrix;

h) removing at least one of the eigenvectors thereby creating a subspace;

i) determining a value that is indicative of the extent a test vector may be represented by the subspace, and wherein the test vector is based on an estimated acoustic velocity of the earth formation;

j) plotting the value as a function of the estimated acoustic velocity of the earth formation and the selected frequency;

k) repeating steps i) and j) for a plurality of estimated acoustic velocities; and

l) repeating steps e) through k) for a plurality of selected frequencies.

22. (Original) The method of determining acoustic velocity and frequency dispersion as defined in claim 21 further comprising:

wherein step a) further comprises sending acoustic energy into the earth formation at a depth level of interest; and

m) repeating steps a) through l) for a plurality of depth levels of interest.

23. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 21 wherein step a) further comprises sending acoustic energy into the earth formation using an acoustic transmitter.

24. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 21 wherein step b) further comprises detecting the acoustic energy in the earth formation with four acoustic receivers.

25. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 21 wherein step h) further comprises removing at least one higher order eigenvector, the removed at least one higher order eigenvector corresponding to desired acoustic signals, and the remaining eigenvectors corresponding to noise.

26. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 25 wherein step i) further comprises applying a test vector to the subspace with the result of the applying being the value indicative of the extent the test vector may be represented by the remaining eigenvectors corresponding to noise.

27. (Previously Amended) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 26 wherein applying a test vector to the subspace with the result of the applying being the value indicative of the extent the test vector may be represented by the remaining eigenvectors corresponding to noise further comprises applying substantially the following equation:

$$\text{result} = \frac{1}{|N_f W_f|^2}$$

where N_f is the subspace and W_f is the test vector.

28. (Original) The method of determining acoustic velocity and frequency dispersion of an earth formation as defined in claim 27 wherein the test vector takes substantially the form:

$$W_f = [1\ e^{-jds}\ e^{-j2ds}\ e^{-j3ds}\ \ldots\ e^{-j(n-r)ds}]$$

where d is the distance between the receivers, s is the estimated acoustic velocity, n is the total number of received signals and r is the number of removed eigenvectors.

APPENDIX B
KIMBALL'S FIGURES 5A, 5B AND 5C

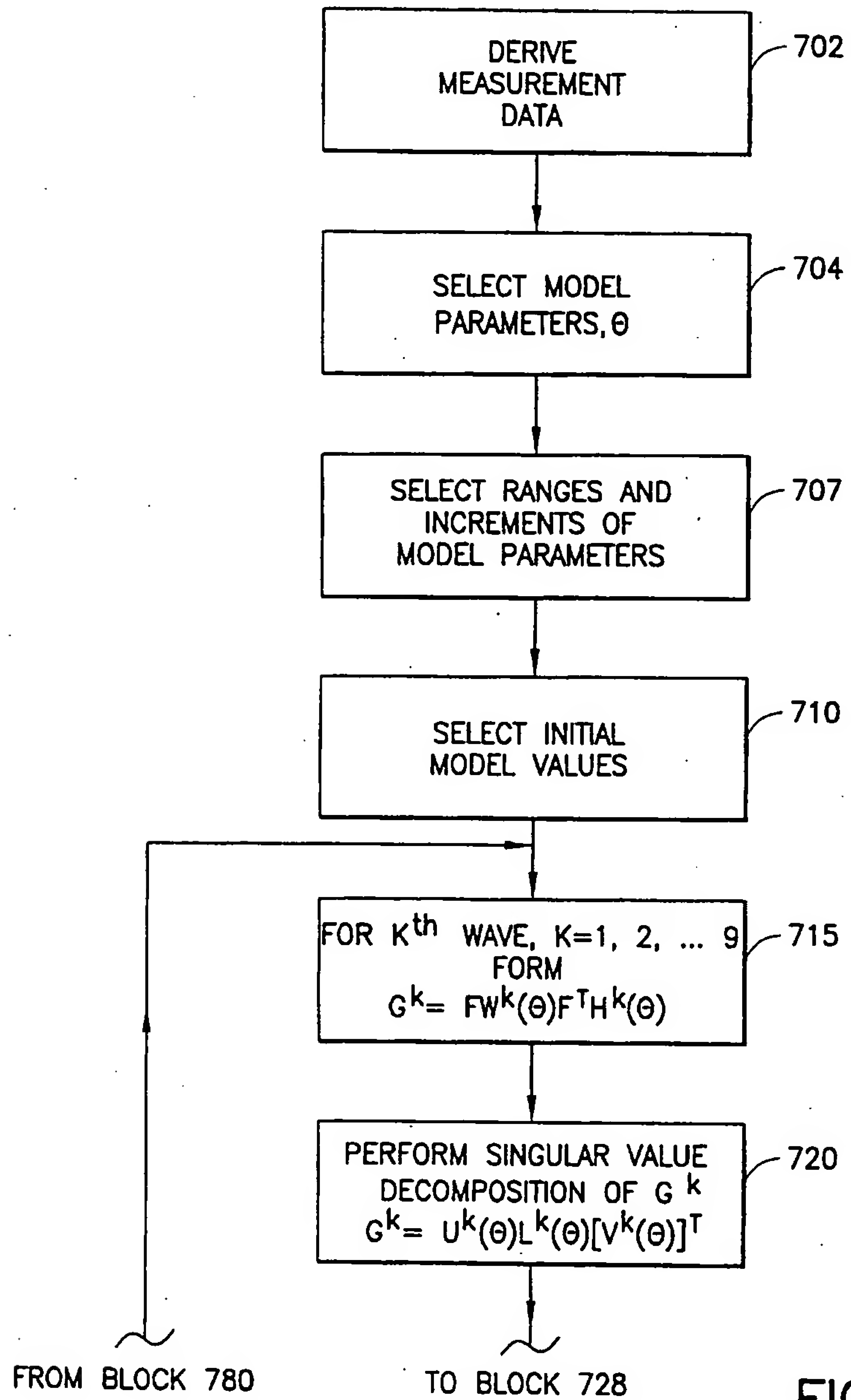

FIG.5A

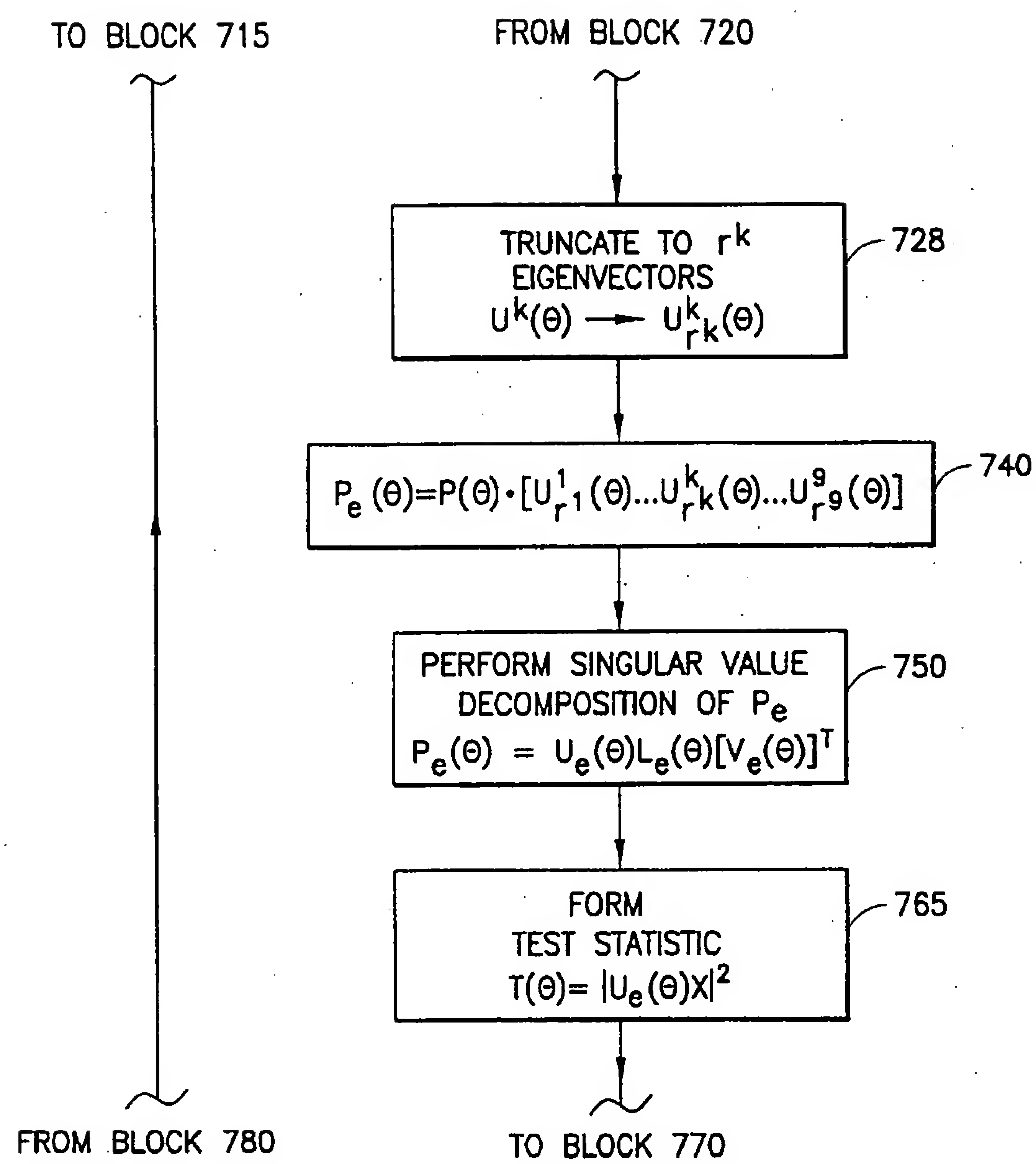
TO BLOCK 715
FROM BLOCK 720
TRUNCATE TO r^k EIGENVECTORS
$U^k(\Theta) \longrightarrow U^k_{r^k}(\Theta)$
728
$P_e(\Theta)=P(\Theta)\cdot[U^1_{r^1}(\Theta)\ldots U^k_{r^k}(\Theta)\ldots U^9_{r^9}(\Theta)]$
740
PERFORM SINGULAR VALUE DECOMPOSITION OF P_e
$P_e(\Theta) = U_e(\Theta)L_e(\Theta)[V_e(\Theta)]^T$
750
FORM TEST STATISTIC
$T(\Theta)= |U_e(\Theta)X|^2$
765
FROM BLOCK 780
TO BLOCK 770

FIG.5B

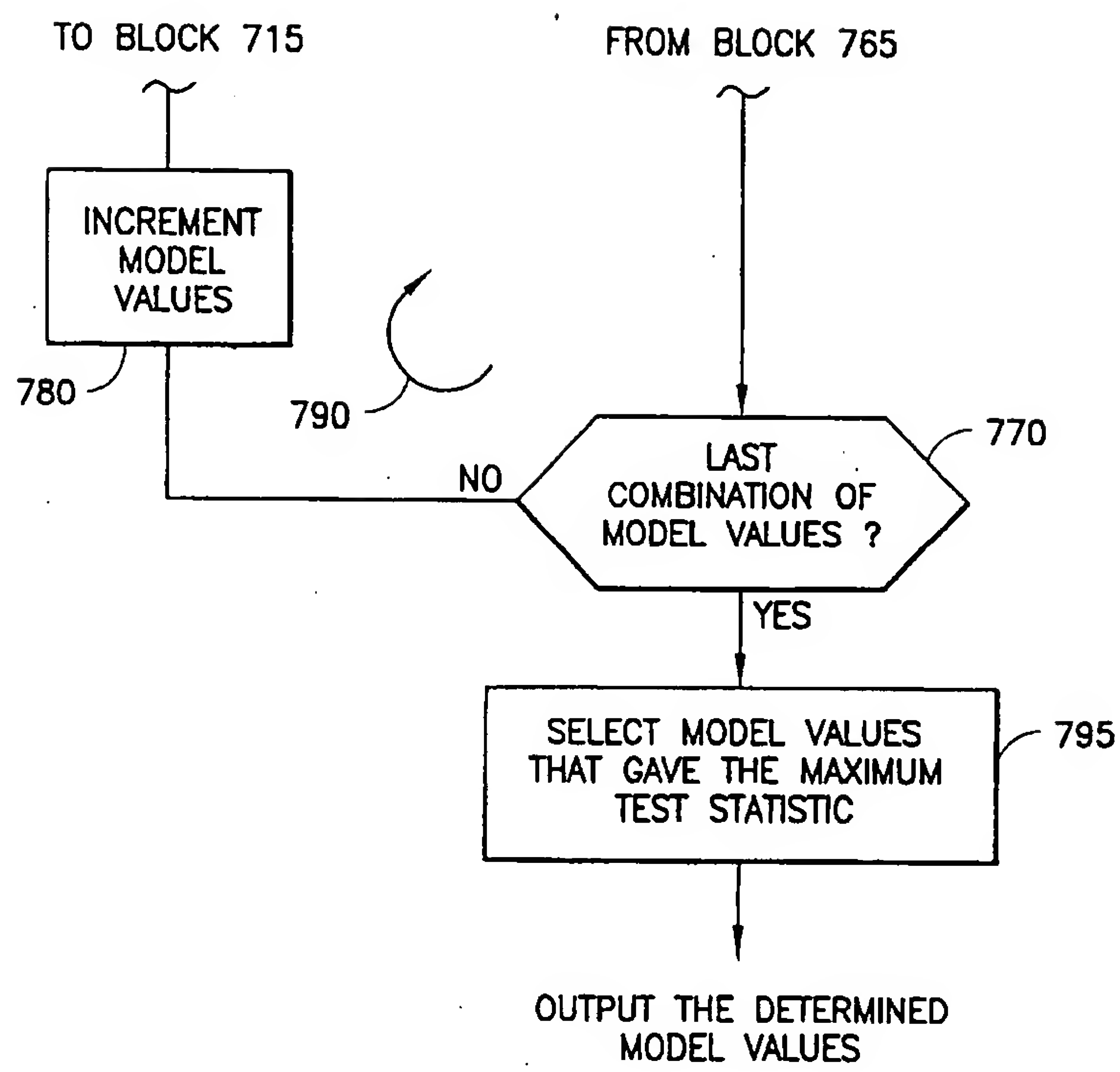
TO BLOCK 715
FROM BLOCK 765
INCREMENT MODEL VALUES
780
790
NO
LAST COMBINATION OF MODEL VALUES ?
770
YES
SELECT MODEL VALUES THAT GAVE THE MAXIMUM TEST STATISTIC
795
OUTPUT THE DETERMINED MODEL VALUES

FIG.5C